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Environmental Kuznets Curve hypothesis in Pakistan: Cointegration and Granger causality

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ABSTRACT

The paper is an effort to fill the gap in the energy literature with a comprehensive country study of Pakistan. We investigate the relationship between CO_2 emissions, energy consumption, economic growth and trade openness in Pakistan over the period of 1971–2009. Bounds test for cointegration and Granger causality approach are employed for the empirical analysis. The result suggests that there exists a long-run relationship among the variables and the Environmental Kuznets Curve (EKC) hypothesis is supported. The significant existence of EKC shows the country's effort to condense CO_2 emissions and indicates certain achievement of controlling environmental degradation in Pakistan. Furthermore, we find a one-way causal relationship running from economic growth to CO_2 emissions. Energy consumption increases CO_2 emissions both in the short and long runs. Trade openness reduces CO_2 emissions in the long run but it is insignificant in the short run. In addition, the change of CO_2 emissions from short run to the long span of time is corrected by about 10% yearly.

Contents

1. Introduction

In any economy, sustainable economic development can be achieved by sustainable environment development. The government of Pakistan launched an environmental policy in 2005 to control environmental degradation with sustained level of economic growth. The main objective of the National Environmental Policy (NEP) is to protect, conserve and restore Pakistan's environment in order to improve the quality of life through sustainable development. Meanwhile, economic growth is stimulated by all sectors of the economy including agricultural, industrial and services. The aggressive growth rate in Pakistan is led by the industrial sector generally and manufacturing sector particularly.[1] On the other hand, this industrial-led growth also increases energy demand and thus environmental pollutants in the country. In 2002–2003, the industrial sector consumed 36% of total energy consumption while 33% is consumed by the transportation. Even though total energy consumption declined to 29% in 2008–2009, but the consumption by industrial sector has been increased to 43%.[2]

For the case of Pakistan, high usage of petroleum in meeting transportation demand is a major reason of rising CO_2 emissions.[3] A considerable share (>50%) of CO_2 emissions is coming from natural gas mainly used by electricity production. In 2005, 0.4% of the world

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[1] In 2009, economic growth rate is 2% due to poor performance of the industrial and manufacturing sectors (Economic Survey of Pakistan, 2008–2009).
[2] Economic Survey of Pakistan, 2008–2009, p. 226.
[3] The nature of transportation has been converted to compressed gas consumption after hike in petroleum prices.

total CO_2 emissions were produced in Pakistan and this "contribution" is worsening daily. While the income per capita has increased from PRS 32,599 to PRS 36,305 over 2006–2009, the usage of energy per capita was increased from 489.36 (kg of oil equivalent) in 2006 to 522.66 (kg of oil equivalent) in 2009. This has led CO_2 emissions per capita raised from 0.7657 metric tons to 1.026 metric tons over the 2006–2009 periods.

Kuznets [1] postulated that income inequality first rises and then falls with economic growth. Named after him, the Environmental Kuznets Curve (EKC) is a hypothesized relationship between environmental degradation and income per capita. The basic idea is simple and intuitive. In the early stages of economic growth, environmental degradation and pollution tend to increase. After a certain level of income has been achieved, economic growth declines as well as the environmental degradation and pollution. Hence, the model is specified in quadratic form of income. Environmental degradation under this approach is a monotonically rising function in income with an "income elasticity" less than unity.

Time effect can reduce the environmental impacts regardless of income level. Generally, the scale effect dominates in the fast growing and middle income economies. As such, increases in pollution and other degradations tend to overwhelm the time effect. In the developed economies, growth rate is slower and pollution reduction efforts can overcome the scale effect. This argument provides the foundation of EKC effect. As the recent evidences suggested, many developing economies are addressing and even remedying the pollution problems (Dasgupta et al. [2]).

On the other hand, globalization leads to the greater integration of economies and societies (Agenor [3]). Thus, new trade routes have been discovered and technology of transport has been improved to obtain benefits from openness. Heckshero–Ohlin (Heckosher [4] and Ohlin [5]) model posits that differences in labor productivity lead to the production of different goods in different economies. Trade is the main engine that provides a way to enhance production intensively by utilizing abundant domestic resources efficiently.[4] Trade openness also provides a way for mobilizing factors of production freely between countries. However, movement of factors of production may also move dirty industries from home countries to developing economies where laws and regulations about the environment is just a formality. For example, Feridun et al. [7] documented that trade openness harms the environmental quality in less developed economies like Nigeria.

Antweiler et al. [8] examined the effect of trade on environmental quality. They introduced composition, scale and technological effects by decomposing the trade model. Their study concluded that trade openness is beneficial to the environment if the technological effect is greater than the composition effect and scale effect. This finding shows that international trade will improve the income level of developing nations and induce them importing less polluted techniques to enhance the production. Copeland and Taylor [9] supported that international trade is beneficial to environmental quality through environmental regulations and capital-labor channels. The authors documented that free trade declines CO_2 emissions because international trade will shift the production of pollution-intensive goods from developing countries to the developed nations. Managi et al. [10] found that the quality of the environment is improved if the environmental regulation effect is stronger than the capital-labor effect. Similarly, McCarney and Adamowicz [11] suggested that trade openness improves environmental quality depending on government policies. The local government can reduce CO_2 emissions through their environmental policies.

[4] See Barro and Sala-i-Martin [6] for more details.

The present study is an effort to fill the gap in the energy literature because there is lack of comprehensive studies for Pakistan. Single country studies help policy making authorities in making comprehensive policy to control environmental degradation. This study contributes to the energy literature with a case study of Pakistan using time series data for the period of 1971–2009. Moreover, an important variable, trade openness is taken into account for its impact on environmental pollution. Technically, we apply ARDL bounds approach to cointegration and Gregory and Hansen [12] structural break cointegration test to examine the long-run relationship of variables. The rest of the paper is organized as follows: literature review is explained in Section 2. Section 3 describes the model. The empirical results are reported in Section 4 and finally, conclusion and policy implications are drawn in Section 5.

2. Literature review

The literature shows two strands of linkage between energy consumption and CO_2 emissions i.e. economic growth and CO_2 emissions and, economic growth and energy consumption. The relationship between CO_2 emissions and economic growth is also termed as EKC.[5] EKC reveals that economic growth is linked with high CO_2 emissions initially and CO_2 emissions tends to decrease as an economy achieves a turning point or threshold level of economic growth.

Empirical studies of EKC started by Grossman and Krueger [13] and followed by Lucas et al. [14], Wyckoff and Roop [15], Suri and Chapman [16], Heil and Selden [17], Friedl and Getzner [18], Stern [19], Nohman and Antrobus [20], Dinda and Coondoo [21] and Coondoo and Dinda [22]. Existing studies seem to present mixed empirical evidences on the validity of EKC. Song et al. [23], Dhakal [24], Jalil and Mahmud [25], and Zhang and Cheng [26] supported the existence of EKC but Wang et al. [27] are contrary with the hypothesis. The findings of Fodha and Zaghdoud [28] revealed the existence of EKC between SO_2 emissions and economic growth in Tunisia but not for the CO_2 emissions. In contrast, Akbostanci et al. [29] did not support the existence of EKC in Turkey. They argued that CO_2 emissions are automatically reduced with the rapid pace of economic growth.

The relationship of energy consumption and economic growth has been investigated extensively as well. For example, Kraft and Kraft [30] for the US, Masih and Masih [31] for Taiwan and Korea, Aqeel and Butt [32] for Pakistan, Wolde-Rufael [33] for African, Narayan and Singh [34] for Fiji, Reynolds and Kolodziej [35] for Soviet Union, Chandran et al. [36] for Malaysia, Narayan and Smyth [37] for Middle Eastern, and Yoo and Kwak [38] for South America concluded that energy consumption causes economic growth. Opposite causality is also found running from economic growth to energy consumption by Altinay and Karagol [39], Khalil and Inam [40] and Halicioglu [41] for Turkey; Squali [42] for OPEC, Yuan et al. [43] for China and Odhiambo [44] for Tanzania. Bivariate causality between energy consumption and economic growth is also documented by Asafu-Adjaye [45] for Thailand and the Philippines.

Recent literature documented an alliance of economic growth with energy consumption and environmental pollution to investigate the validity of EKC. The relationship between economic growth, energy consumption and CO_2 emissions have also been researched extensively both in a country case and panel studies. Ang [46] found stable long-run relationship between economic growth, energy consumption and CO_2 emissions for the French economy while Ang [47] also got similar result for Malaysia. Ang [46] showed that causality is running from economic growth to

[5] The relationship is described by the linear and non-linear terms of GDP per capita in the model.

energy consumption and CO_2 emissions in the long run but energy consumption causes economic growth in the short run. In the case of Malaysia, Ang [47] reported that output increases CO_2 emissions and energy consumption. Ghosh [48] documented that no long-run causality between economic growth and CO_2 emissions but has bivariate short-run causality in India. Alam et al. [49] reported feedback hypothesis between energy consumption and energy pollutants but no causality is found among CO_2 emissions, energy consumption and economic growth.

For panel studies, Apergis and Payne [50] investigated the relationship between CO_2 emissions and economic growth for six Central American economies using panel VECM. Their empirical evidence showed that energy consumption is positively linked with CO_2 emissions and that the EKC hypothesis has been confirmed. Lean and Smyth [51] and Apergis and Payne [52] reached the same conclusion for the case of ASEAN and Commonwealth of Independent States countries, respectively. Narayan and Narayan's [53] empirical evidence also validated the EKC hypothesis for 43 low income countries. In addition, Lean and Smyth [51] noted a long-run causality running from energy consumption and CO_2 emissions to economic growth but in a short span of time, energy consumption causes CO_2 emissions. On the other hand, Apergis and Payne [52] found that energy consumption and economic growth Granger causes CO_2 emissions while bivariate causality is found between energy consumption and economic growth; and between energy consumption and CO_2 emissions.

The relationship between international trade and environment has also been investigated empirically. Grossman and Krueger [13] argued that the environmental effects of international trade depend on the policies implemented in an economy. There are two schools of thought about the impact of international trade on CO_2 emissions. The first school of thought argued that trade openness provides an offer to each country to have access to international markets which enhances the market share among countries. This leads to competition between countries and increases the efficiency of using scarce resources and encourages importing cleaner technologies in order to lower the CO_2 emissions (e.g. Runge [54] and Helpman [55]). Another group proposed that natural resources are depleted due to international trade. This depletion of natural resources raises CO_2 emissions and causes a decrease in environmental quality (e.g. Schmalensee et al. [56], Copeland and Taylor [57], and Chaudhuri and Pfaff [58]).

In country case studies, Machado [59] indicated a positive link between foreign trade and CO_2 emissions in Brazil. Mongelli et al. [60] concluded that the pollution haven hypothesis existed in Italy.[6] Halicioglu [41] added trade openness to explore the relationship between economic growth, CO_2 emissions and energy consumption in Turkey. Their results showed that trade openness is one of the main contributors to economic growth while income raises the level of CO_2 emissions. Chen [62] explored this issue in Chinese provinces and documented that industrial sector's development is linked with an increase of CO_2 emissions due to energy consumption.[7] Pao and Tsai [63] confirmed the presence of EKC in Brazil, Russia, India and China. Ozturk and Acaravci [64] indicated that EKC is valid in Turkey while Acaravci and Ozturk [65] validated the existence of EKC in Demark and Italy. Nasir and Rehman [66] used ADF unit root test and Johansen and Juselius [67] cointegration test also supported EKC in Pakistan. Iwata et al. [68] investigated empirically the existence of EKC in 28 countries including Pakistan.

3. Model and methodology

Different approaches have been used to investigate the relationship between economic growth, CO_2 emissions and natural resources. Jorgenson and Wilcoxen [69] and Xepapadeas [70] modeled the linkages between energy consumption, environment pollutants and economic growth in equilibrium framework with an aggregate growth model. A recent strand of research has explored the linkages between economic growth and CO_2 emissions, and energy consumption and CO_2 emissions in a single equation model (Ang [46,47] and Soytas et al. [71]). The present study follows the methodology applied by Ang [46,47], Soytas et al. [71], Halicioglu [41] and Jalil and Mahmud [25].[8]

The relationship between CO_2 emissions and energy consumption, economic growth and trade openness can be specified as follows:

$$CO_{2t} = f(ENC_t, GDP_t, GDP_t^2, TR_t) \quad (1)$$

where CO_2 is CO_2 emissions per capita, ENC is energy consumption per capita, GDP (GDP^2) is real GDP (squared) per capita and TR is trade openness (exports + imports) per capita. The linear model is converted into log-linear specification as it provides more appropriate and efficient results compare to the simple linear functional form of model (see Cameron [72] and Ehrlich [73,74]). Hence, the equation is re-written as follows:

$$\ln\ CO_{2t} = \beta_1 + \beta_{ENC} \ln ENC_t + \beta_{GDP} \ln GDP_t + \beta_{GDP^2} \ln GDP_t^2 + \beta_{TR} \ln TR_t + \mu_t \quad (2)$$

where μ_t is the error term.

It is expected that economic activity is stimulated with an increase in energy consumption that therefore causes increase of CO_2 emissions. This leads us to expect $\beta_{ENC} > 0$. The EKC hypothesis reveals that $\beta_{GDP} > 0$ while the sign of GDP^2 should be negative or $\beta_{GDP^2} < 0$. The expected sign of trade openness is negative, $\beta_{TR} < 0$ if production of pollutant intensive items is reduced due to the environment protection laws. However, Grossman and Helpman [75] and Halicioglu [41] argued that the sign of β_{TR} is positive if dirty industries of developing economies are busy producing a heavy share of CO_2 emissions with their production processes.

Pesaran et al. [76] established ARDL bounds testing approach to examine cointegration among variables. The ARDL approach can be applied without investigating the order of integration of variables (Pesaran and Pesaran [77]). Moreover, Haug [78] argued that the ARDL approach for cointegration presents better result for small sample as compared to other cointegration techniques such as Engle and Granger [79], Johansen and Juselius [67] and Phillips and Hansen [80].

Furthermore, the unrestricted error correction model (UECM) seems to take satisfactory lags that captures the data generating process in a general-to-specific framework of specification (Laurenceson and Chai [81]). However, Pesaran and Shin [82] contented that "appropriate modification of the orders of the ARDL model is sufficient to simultaneously correct for residual serial correlation and the problem of endogenous variables". The UECM is constructed to examine long-run and short-run relationships

[6] The pollution haven hypothesis reveals that in order to attract foreign investment, the governments of developing countries have a tendency to undermine environment concerns through relaxed or non-enforced regulation reported by Hoffmann et al. [61].

[7] Zhang and Cheng [26] concluded that GDP growth causes energy consumption while energy consumption causes CO_2 emissions.

[8] Halicioglu [41] and Jalil and Mahmud [25] included foreign trade as an independent factor in their models to examine the impact of foreign trade on environmental pollutants.

Table 1
Clemente-Montanes-Reyes detrended structural break unit root test.

Variable	Innovative outliers				Additive outlier			
	t-Statistic	TB1	TB2	Decision	t-Statistic	TB1	TB2	Decision
$\ln CO_{2,t}$	−3.627 (3)	1978	2002	$I(0)$	−11.493 (3)[*]	1978	1989	$I(1)$
$\ln ENC_t$	−3.768 (4)	1978	1985	$I(0)$	−6.805 (3)[**]	1986	2006	$I(1)$
$\ln GDP_t$	−4.921 (1)	1978	2002	$I(0)$	−6.768(4)[**]	1991	2003	$I(1)$
$\ln GDP_t^2$	−4.445 (4)	1978	2002	$I(0)$	−6.650 (3)[**]	1991	2003	$I(1)$
$\ln TR_t$	−4.192 (3)	1977	1990	$I(0)$	−5.842 (4)[**]	1994	2001	$I(1)$

Note: Lag order is in the parenthesis.
[*] Indicate significant at 1% level of significance, respectively.
[**] Indicate significant at 5% level of significance, respectively.

among variables as follows:

$$\Delta\ \ln CO_{2t} = \alpha_0 + \alpha_1 T + \sum_{i=1}^{p}\beta_i\ \ln CO_{2,t-i} + \sum_{i=0}^{q}\delta_i \ln ENC_{t-i} + \sum_{i=0}^{r}\varepsilon_i \ln GDP_{t-i} + \sum_{i=0}^{s}\sigma_i \ln GDP^2_{t-i} + \sum_{i=0}^{t}\omega_i \ln TR_{t-i} + \lambda_{CO_2} \ln CO_{2,t-1} + \lambda_{ENC} \ln ENC_{t-1} + \lambda_{GDP} \ln GDP_{t-1} + \lambda_{GDP^2} \ln GDP^2_{t-1} + \lambda_{TR} \ln TR_{t-1} + \mu_t \tag{3}$$

Eq. (3) presents two segments of results. The first part indicates the short-run parameters such as β, δ, ε, σ and ω while λs (λ_{CO_2}, λ_{ENC}, λ_{GDP}, λ_{GDP^2}, λ_{TR}) explore the long-run associations between variables of interest. The hypothesis of no cointegration i.e. $\lambda_{CO_2} = \lambda_{ENC} = \lambda_{GDP} = \lambda_{GDP^2} = \lambda_{TR} = 0$ is examined. The decision of cointegration is based on the computed F-statistic. The F-statistic is then comparing with the critical bounds that were tabulated by Pesaran and Pesaran [77].[9] The upper critical bound (UCB) is based on the assumption that all variables are integrated at one and the lower critical bounds (LCB) assume variables are $I(0)$. If UCB is lower than the F-statistic, then the decision is in favor of cointegration among the variables. This indicates the existence of a long-run relationship between the variables. If the F-statistic is less than LCB, then it favors to no cointegration among the variables. The decision about cointegration will be inconclusive if the F-statistic falls between UCB and LCB. In such situations, we will have to rely on the finding of the lagged error correction term (ECT) to investigate the long-run relationship. If there is a long-run relationship between variables, the short-run behavior of variables is investigated by the following VECM model:

$$\Delta \ln CO_{2,t} = \delta_0 + \sum_{j=0}^{p}\delta_{1j}\Delta \ln\ ENC_{t-j} + \sum_{j=0}^{p}\delta_{2j}\Delta \ln GDP_{t-j} + \sum_{j=0}^{p}\delta_{3j}\Delta \ln\ GDP^2_{t-j} + \sum_{j=0}^{p}\delta_{4j}\Delta \ln\ TR_{t-j} + \sum_{j=0}^{p}\delta_{5j}\Delta \ln CO_{2,t-j} + \eta ECT_{t-1} + \mu_t \tag{4}$$

It is documented that if the value of lagged ECT is between 0 and −1, then adjustment to the dependent variable in current period is the ratio of error in the previous period. In such situations, ECT causes the dependent variable to converge to long-run equilibrium due to variations in the independent variables. The goodness of fit for ARDL model is also checked with stability tests such as cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals (CUSUMSQ). Finally, sensitivity analysis is also conducted to confirm the model specification.

4. Empirical results

The annual data on CO_2 emissions and energy consumption are obtained from World Development Indicators (WDI CD-ROM [83]). The Economic Survey of Pakistan (2008–09) is used to comb the data for real GDP and trade openness. The sample period covers the years from 1971 to 2009.

Results from traditional unit root tests such as Dickey and Fuller [84], Phillips and Perron [85], Elliott et al. [86], Kwiatkowski et al. [87] and Ng and Perron [88] are biased and unreliable when a series has structural break(s) (Baum [89]). To overcome this problem, we apply Clemente et al. [90] two-break test. The main advantage of this test is that it has information about two possible structural break points in the series by offering two models i.e. an additive outliers (AO) model informing about a sudden change in the mean of a series and an innovational outliers (IO) model indicates about the gradual shift in the mean of the series. The AO model is more suitable for variables that have sudden structural change. The results of Clemente et al. [90] unit root test are reported in Table 1. All series are $I(1)$.

The two-step procedure of ARDL bound test requires lag length of variables. Based on the minimum value of Akaike Information Criteria (AIC), the optimum lag order is (1, 1, 1, 0, 1). Table 2 shows F-statistic is greater than UCB infers cointegration among the variables. The diagnostic tests results confirm the validity of the estimation.

Table 2
ARDL bounds test for cointegration.

Estimated equation	$CO_{2,t} = f(ENC_t, GDP_t, GDP_t^2, TR_t)$	
F-statistics	10.0062[a]	
Significant level	Critical values (T = 39)[b]	
	Lower bounds, $I(0)$	Upper bounds, $I(1)$
1%	7.763	8.922
5%	5.264	6.198
10%	4.214	5.039

Diagnostic tests	Statistics (p-value)
R^2	0.8137
Adjusted-R^2	0.6952
J-B normality	0.9537 (0.6207)
Breusch-Godfrey LM	0.5885 (0.4515)
ARCH LM	0.0094 (0.9232)
Ramsey RESET	0.3780 (0.5452)

[a] Significant at 1%.
[b] Critical values bounds are computed by surface response procedure by Turner [91].

[9] We use Turner's [91] critical values instead of Pesaran and Pesaran [77] and Narayan [99] because the lower and upper bounds by Turner [91] are more suitable for small sample.

Table 3
Gregory–Hansen cointegration test.

Estimated model	$CO_{2,t} = f(ENC_t, GDP_t, GDP_t^2, TR_t, DUM_t)$
ADF t-statistics	−7.4842*

* Shows significance at 10% level of significance.

We also employ Gregory and Hansen [12] cointegration test to examine the robustness of long-run relationship. Gregory–Hansen cointegration test is more powerful than residual based cointegration tests and allows the presence of one structural break in the series. We find cointegration exists between energy consumption, economic growth, trade openness and CO_2 emissions after allowing a break in 1995 (Table 3). The break point is due to the implementation of trade reform in removing trade deficit under the umbrella of structural adjustment program forced by IMF.

The long-run marginal impacts of economic growth, energy consumption and trade openness on CO_2 emissions are reported in Table 4. The result reveals that a 1% rise in energy consumption raises CO_2 emissions by 0.86%. This finding is in line with Hamilton and Turton [92], Friedl and Getzner [18], Liu [93], Ang and Liu [94], Say and Yucel [95], Ang [46], Halicioglu [41], Jalil and Mahmud [25].

Both linear and non-linear terms of real GDP provide evidence in supporting inverted-U relationship between economic growth and CO_2 emissions. The result indicates that a 1% rise in real GDP will raise CO_2 emissions by 3.75% while negative sign of squared term seems to corroborate the delinking of CO_2 emissions and real GDP at the higher level of income. These evidences support the EKC hypothesis revealing that CO_2 emissions increase in the initial stage of economic growth and decline after a threshold point. This finding is consistent with He [96], Song et al. [23], Halicioglu [41], Fodha and Zaghdoud [28] and Lean and Smyth [51].

On the other hand, TR shows inverse impact on CO_2 emissions. We find that 0.09% of CO_2 emissions are declined with 1% increase in international trade. Our finding supports the view by Antweiler et al. [8], Copeland and Taylor [9], McCarney and Adamowicz [11] and Managi et al. [10] that foreign trade reduces CO_2 emissions through technological effect in the country. However, this finding is contrary to Khalil and Inam [40] who probed that international trade is harmful to environmental quality in Pakistan and Halicioglu [41] who posited that foreign trade increases CO_2 emissions in Turkey. Sharma [100] also reported the same inference. The high value of R-squared and a battery of diagnostic tests confirm good fit of the estimated model and stability of long-run results.

Table 4
Long-run relationship.

Variable	Coefficient	t-Statistic	Probability
Dependent variable = $\ln CO_{2,t}$			
Constant	−59.5359	−4.4192	0.0001
$\ln ENC_t$	0.8644	4.6376	0.0001
$\ln GDP_t$	3.7483	3.9443	0.0004
$\ln GDP_t^2$	−0.0506	−3.0698	0.0044
$\ln TR_t$	−0.0855	−1.7927	0.0828

R^2 = 0.9987
Adjusted R^2 = 0.9985
Akaike info criterion = −4.4858
Schwarz criterion = −4.2659
F-statistic = 6007.3990
Prob(F-statistic) = 0.0000
Durbin–Watson = 1.9820
Sensitivity analysis
Serial correlation LM = 0.3033 (0.7406)
ARCH test = 0.3210 (0.5747)
Normality test = 2.0552(0.3578)
Heteroscedisticity test = 0.4458 (0.8118)
Ramsey reset test = 1.9746 (0.1570)

Table 5
Granger causality test.

	F-statistic	Prob. value
Long-run causality		
$\ln GDP_t$ does not Granger cause $\ln CO_{2,t}$	4.0537	0.0160
$\ln CO_{2,t}$ does not Granger cause $\ln GDP_t$	0.9634	0.4232
$\ln GDP_t^2$ does not Granger cause $\ln CO_{2,t}$	3.8977	0.0186
$\ln CO_{2,t}$ does not Granger cause $\ln GDP_t^2$	0.9183	0.4442
Short-run causality		
$\Delta\ln GDP_t$ does not Granger cause $\Delta\ln CO_{2,t}$	4.9524	0.0136
$\Delta\ln CO_{2,t}$ does not Granger cause $\Delta\ln GDP_t$	0.2798	0.7577
$\Delta\ln GDP_t^2$ does not Granger cause $\Delta\ln CO_{2,t}$	4.3145	0.0222
$\Delta\ln CO_{2,t}$ does not Granger cause $\Delta\ln GDP_t^2$	0.2811	0.7567

Table 6
Short-run relationship.

Variable	Coefficient	t-Statistic	Probability
Dependent variable = $\Delta\ln CO_{2,t}$			
Constant	0.0303	7.3531	0.0000
$\Delta\ln ENC_t$	0.6077	2.2670	0.0308
$\Delta\ln GDP_t$	11.3108	2.0736	0.0468
$\Delta\ln GDP_t^2$	−0.5283	−1.9280	0.0634
$\Delta\ln TR_t$	−0.0582	−1.4275	0.1637
ECM_{t-1}	−0.1021	−6.1286	0.0000

R^2 = 0.6605
Adjusted R^2 = 0.6039
Akaike info criterion = −4.4690
Schwarz criterion = −4.2050
F-statistic = 11.6730
Prob (F-statistic) = 0.0000
Durbin–Watson = 2.1142
Sensitivity analysis
Serial correlation LM = 0.8992 (0.4596)
ARCH test = 0.0216 (0.8839)
Normality test = 0.4129 (0.8134)
Heteroscedisticity test = 0.6739 (0.7377)
Ramsey reset test = 0.1405 (0.7104)

We then examine the direction of causality between economic growth and CO_2 emissions with Granger causality test. Results in Table 5 indicate that real GDP (real GDP squared) Granger causes CO_2 emissions in the long run as well as in the short run. The causality result also confirms the existence of EKC (see for example, Coondoo and Dinda [22]; Dinda and Coondoo [21]; Akbostanci et al. [29] and Lee and Lee [97]). This empirical evidence is similar to the findings of Maddison and Rehdanz [98] for North America, Zhang and Cheng [26] and Jalil and Mahmud [25] for China and Ghosh [48] for India.

The short-run dynamics results are reported in Table 6. It is noted that a 1% rise in energy consumption will increase CO_2 emissions by 0.6%. The sign of coefficient of GDP and GDP^2 validates again the existence of an inverted-U Kuznets curve in the short run. It is noted that the long-run income elasticity for CO_2 emissions is less than the short-run elasticity for CO_2 emissions. This further proves the existence of EKC.[10] The short-run effect of international trade is also negative but insignificant.

The sign of coefficient of lagged ECM term is negative and significant at 1% level of significance. This confirms the established of long-run relationship among the variables. Furthermore, the value of lagged ECM term entails that change in CO_2 emissions from short run to long run is corrected by almost 10% per year. The diagnostic tests findings show that the short-run model passes all diagnostic tests. We find no serial correlation, no autoregressive conditional heteroskedasticity and White heteroskedasticity, the residual term is normally distributed and the functional form of the model is well

[10] For more details, please refer to Narayan and Narayan [53].

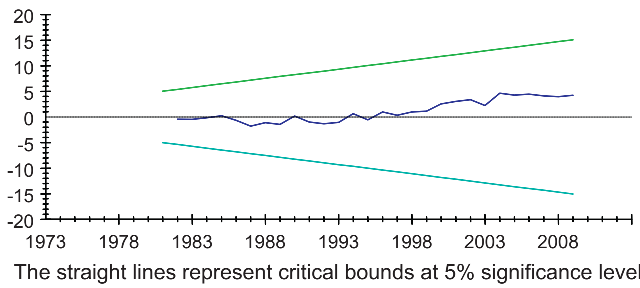

Fig. 1. Plot of cumulative sum of recursive residuals.

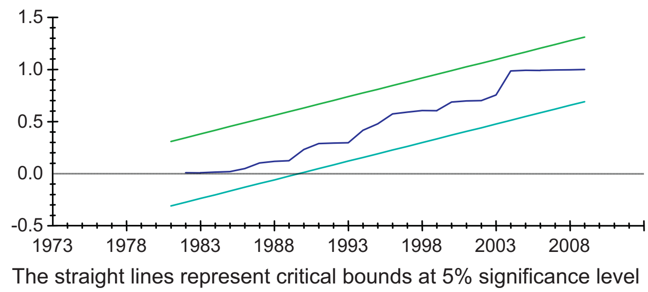

Fig. 2. Plot of cumulative sum of squares of recursive residuals.

specified. Figs. 1 and 2 specify that plots of CUSUM and CUSUMSQ are within the 5% critical boundaries. This confirms the accuracy of long- and short-run parameters in the model.

5. Conclusion and policy implications

This paper investigates the relationship between CO_2 emissions, energy consumption, economic growth and trade openness in Pakistan over the period of 1971–2009. The result suggests that there exists a long-run relationship among the variables. The positive sign of linear and negative sign of non-linear GDP indicate that EKC hypothesis is supported in the country. The result of Granger causality test shows one-way causal relationship running from income to CO_2 emissions. Energy consumption increases CO_2 emissions in both short and long runs. Openness to trade reduces CO_2 emissions in the long run but it is insignificant in the short run.

The significant existence of EKC shows that the country's effort to condense CO_2 emissions. This indicates the reasonable achievement of controlling environmental degradation in Pakistan since the Government implemented NEP in 2005. However, findings based on aggregate data may not be able to show the pattern of four provinces individually. The implementation of NEP itself is not enough. Effective enforcement of environmental laws and regulation is necessary not only at the federal level but also at the provincial level. Furthermore, research and development activities on environmental degradation which are important to attain sustainable development are still unattainable in Pakistan. Therefore, to curb CO_2 emissions, there is a need to implement environmental taxes such as green tax.

Moreover, trade openness has beneficial impact on the environmental quality in Pakistan. This supports Antweiler et al. [8] that international trade does not harm the environment if the country uses cleaner technology for production after achieving a sustainable level of development. Hence, we suggest that Pakistan may import cleaner technology for its industrial sector. This will enhance the production level and also becomes a safety valve against environmental degradation. Keeping the composition effect constant, scale effect stimulates economic growth. Industrial pollution can be reduced if government checks on scale effect by importing cleaner technology for the industrial sector to attain maximum gain from international trade.

The limitation of our study is the growth pattern of four provinces of Pakistan is different. For future research, studies can focus on the provincial level in order to attain a comprehensive impact of economic growth on CO_2 emissions which will provide new insights to policy makers in controlling environmental degradation at provincial level.

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